MAP-I

Joint doctoral programme in Computer Science of Universidade do Minho, Universidade de Aveiro and Universidade do Porto

2009/10 Course Edition

System Software and Applications for Ambient Intelligence

Teaching Team

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A. Course Description

1. Overview and Context

This document describes a course on "**System Software and Applications for Ambient Intelligence**" to be offered as part of the 2009/10 edition of the Joint doctoral programme in Computer Science of Universidade do Minho, Universidade de Aveiro and Universidade do Porto (MAP-I).

The course introduces students to the general topics of ubiquitous and pervasive computing and is particularly focused in systems and applications for Ambient Intelligence. At the end of this course, students should be able to create systems that explore the enormous innovation potential raised by the increasingly pervasive presence of information technologies in all aspects of our everyday life. This corresponds to an emerging need in the market for people that are skilled in designing, developing, deploying and evaluating Ambient Intelligence systems.

The course is organised by researchers from the Universities of Minho and Porto with a vast and complimentary research and teaching experience in the field of Ubiquitous Computing and Ambient Intelligence. This course has already been offered as part of the 2008/09 MAP-I edition, where it was one of the options running as part of the UC on Computing Paradigms. The current proposal is largely based on the experience of that previous edition, but has been revised and has been complemented with an additional emphasis on Ambient Assisted Living, making it more aligned with the topic of eHealth, the theme of this edition.
The course is being proposed to be one of the options in the UC on Computing Paradigms (as it was offered in the previous edition), even though it may also be offered as part of the option on Technologies.

Ambient Intelligence

Research labs such as Fraunhofer and industrial manufacturers such as Philips have been promoting the Ambient Intelligence paradigm in which people interact with an environment that is personalized to people's tastes, anticipates people's behaviour, and is proactive in satisfying people's needs. Ambient Intelligence builds on the paradigm of Ubiquitous Computing, where computation is embedded into everyday objects, where everything communicates with everything else, and where virtual and physical environments are closely interconnected. With computing devices becoming progressively smaller and more powerful, it is sensible to expect that almost any object, from clothing to coffee mugs, will be embedded with some sort of computational capability and able to connect to any other device. This enables Ambient Intelligence and will dramatically change our perception of what a computer system is, as the entire environment with all its integrated devices and associated services becomes indistinguishable from the computer. In such a scenario, the environment becomes the interface and computation devices, as we currently know them, fade into the background. Ambient Intelligence and Ubiquitous Computing systems are thus radically different from traditional distributed systems, and set many new research challenges that cut across various disciplines.

System Software and Applications for Ambient Intelligence

System software for Ambient Intelligence environments has become a particularly active topic of research, its ultimate goal being the creation of a meta-operating system for physical environments. Such software infrastructure should be able to transparently manage the relevant resources and provide an integrated execution environment in which applications, seen here as orchestrated collections of services, could be executed in association with the corresponding physical environment. Many middleware architectures have been proposed that aim to provide the necessary glue to integrate an open, diverse and a priori unknown set of services into a functioning system. Examples include the Event Heap [1], One.World [2], Aura [3] and GAIA [4]. Typical issues include the architectural approach, the discovery, selection and spontaneous interaction between entities, naming, event notification, and the ability to enable cooperation between entities even if separated in time and space. These systems provide some type of programming model that application developers can use to create new applications without having to consider the details of the underlying infrastructure. Research in the area of middleware for Ambient Intelligence environments has been in progress for the last few years, both in academia and industry, and it is now possible to study and compare a diverse number of approaches and their accomplishments.

Applications

Driving the behaviour of the system, applications lay on top of the system software and have to deal with the complexity and diversity of an Ambient Intelligence environment. Issues such as the user experience, privacy, social and legal implications, business models, and user-led system and application innovation must be considered when designing these applications. For example, in Ambient Assisted Living scenarios, in which the environment assists patients or elderly people in their daily tasks, e.g. reminding them to take prescribed medicine, application designers may need to find approaches that enable patient monitoring without clashing into their privacy. Ambient Intelligence scenarios are rich with such applications and challenges. Rather than simply evaluating the final system, interaction design techniques and evaluations are crucial from the beginning, as they play a central role in informing the evolution of the system design in a way that matches the expectations, opportunities and practices of the targeted environment.

Applications Domains

Research and Development in Ubiquitous Computing and Ambient Intelligence is intrinsically related with the application domains for which the technology is created. To convey a more profound perspective of the implications and opportunities in specific application domains, the course also includes the analysis in more detail of two particular application domains. The emphasis is on highlighting the specific issues raised in a particular domain, analyse how they are handled in some reference systems, and discuss the potential of ubiquitous computing and Ambient Intelligence technologies within the scope of specific domains.

References

[1] B. Johanson and A. Fox, "The Event Heap: a coordination infrastructure for interactive workspaces," presented at Fourth IEEE Workshop on Mobile Computing Systems and Applications, 2002.
[2] R. Grimm, J. Davis, E. Lemar, A. MacBeth, S. Swanson, T. Anderson, B. Bershad, G. Borriello, S. Gribble, and D. Wetherall., "System support for pervasive applications.," *ACM Transactions on Computer Systems*, vol. 22 No 4, pp. 421-486, 2004.
[3] J. P. Sousa and D. Garlan, "Aura: an Architectural Framework for User Mobility in Ubiquitous Computing Environments," presented at Software Architecture: System Design, Development, and Maintenance (Proceedings of the 3rd Working IEEE/IFIP Conference on Software Architecture), 2002.
[4] M. Román, C. K. Hess, R. Cerqueira, A. Ranganathan, R. H. Campbell, and K. Nahrstedt, "Gaia: A Middleware Infrastructure to Enable Active Spaces," *IEEE Pervasive Computing* No Oct-Dec., pp. 74-83, 2002.

Scientific areas

C. Computer Systems Organization/ C.2 COMPUTER-COMMUNICATION NETWORKS/ C.2.1 Network Architecture and Design
C. Computer Systems Organization/C.2 COMPUTER-COMMUNICATION NETWORKS/C.2.4 Distributed Systems
D. Software/D.1 PROGRAMMING TECHNIQUES/D.1.3 Concurrent Programming
D. Software/D.2 SOFTWARE ENGINEERING/ D.2.11 Software Architectures
D. Software/ D.2 SOFTWARE ENGINEERING / D.2.12 Interoperability
H. Information Systems/ H.5 INFORMATION INTERFACES AND PRESENTATION/

Similar courses

In recent years, Ubiquitous and Pervasive Computing has become a common topic for graduate courses in computing. For example, for some years, the CMU PhD Programme in Computer Science includes a course on Mobile and Pervasive Computing (http://www.cs.cmu.edu/~15-821/) and another on Research Topics in Ubiquitous Computing (http://www.cs.cmu.edu/~jasonh/courses/ubicomp-sp2007/).
However, and despite the emergence of multiple types of courses dedicated to Ubiquitous and Pervasive Computing, this is still a relatively recent topic for which there is no widely accepted view on the respective body of knowledge. This reality is exacerbated by the inherent multi-disciplinary nature of Ubiquitous and Pervasive Computing, which means that different courses may approach the topic from very diverse perspectives.
In 2003, as multiple courses were spreading everywhere, multiple workshops and papers started addressing the topic of ubiquitous and pervasive computing education. One of the most influential in terms of defining the core body of knowledge associated with pervasive and ubiquitous computing was the *Ubicomp Education: Current Status and Future Directions* [1]. Even though this is not a formal curriculum for ubiquitous and pervasive computing, it remains the most important reference for the structure of such courses and will also be used as the base structure for this course. Those interested in the details of the proposed structure are referred to the IEEE Pervasive Computing article where the workshop conclusions are presented[2].

[1] Abowd, G.D., G. Borriello, and G. Kortuem. Ubicomp Education: Current Status and Future Directions: workshop at Ubicomp 2003, Seattle, USA. 2003. Available from: http://ubicomp.lancs.ac.uk/workshops/education03.

[2] Abowd, G.D., G. Borriello, and G. Kortuem, Report from the Ubicomp Education Workshop. IEEE Pervasive Computing, 2004. 3(1): p. 94-98.

2. Objectives and Learning Outcomes

This course aims to introduce students into the broad topics of Ubiquitous and Pervasive Computing, providing them with the key technological knowledge and methodological approaches for designing, developing, deploying and evaluating systems based on those paradigms. Within the broad set of topics associated with Ubiquitous and Pervasive Computing, this course has a particular focus on software infrastructures for Smart Spaces, working in more detail the challenges and reference approaches for enabling software infrastructures that become integral parts of their physical and social environments.
At the end of this course, students are expected to be able to:

- Explain the general principles of Ubiquitous Computing and the key technical and social factors driving the change towards post-desktop paradigms
- Explain the main implications of Ubiquitous Computing for system design, development and deployment.
- Explain reference approaches used in Ubiquitous Computing and evaluate their applicability in specific application scenarios
- Analyse an existing infrastructure for Ambient Intelligence from the perspective of the key design approaches.
- Realise simple Ambient Intelligence environments that combine virtual and physical, while showing a balanced attention to the relevant technical, social and economical factors involved.
- Understand the role of evaluation at the various design stages and the key evaluation techniques used in ubiquitous computing.

3. Program

A. Introduction to Ubiquitous and Pervasive Computing
    a. General principles
    b. Motivation and key driving factors
    c. Main characteristics of post-desktop computing
    d. The Ambient Intelligence vision

B. Merging the virtual and physical worlds
    a. Integration techniques and technologies
    b. Sensing and modelling the physical environment
    c. Machine learning and activity recognition

C. Interaction Models
    a. New interface concepts
    b. Emerging interaction paradigms
        i. Context-awareness
        ii. Pro-active computing
        iii. Activity-based computing
        iv. Situated interaction

D. Software Architectures for Ambient Intelligence
    a. Key Challenges for software development
    b. Design Principles for Smart Spaces: Volatility, Boundary, Self-configuration, Graceful degradation, and Maintainability
    c. Key services for pervasive computing environments: Context, Location, Discovery, Events, Communication services, Bootstrapping, Security and Privacy.
    d. Service discovery and collaboration patterns
    e. Toolkits and middleware
    f. Application frameworks
    g. Case Studies: Event Heap, Gaia, Aura, Anywhere Places
    h. Collaborative Networks and Group Decision Support Systems

E. Evaluation in ubiquitous computing
    a. Evaluation techniques and processes
    b. Models and prototypes in ubicomp evaluation
    c. Interaction Design for everyday life
    d. Deployment challenges
    e. Open Innovation in Ubiquitous and Pervasive Computing

F. Application Domains
    a. Healthcare Systems and Ambient Assisted Living (AAL)
    b. Urban Computing and Reality Mining
    c. Situated Displays

4. Teaching Methodologies and Assessment

This course corresponds to 5 ECTS involving a broad range of learning activities with a particular focus on active learning techniques. These will be favoured, not only for their ability in stimulating student engagement, but mainly because the learning outcomes proposed for this course include high-level objectives that can only be achieved through the execution, by the students, of analysis, development and discussion tasks. Furthermore, the high quality of the students involved, will contribute to maximise participation and therefore the benefits of the approach. A small practical component is included as part of a system report. Some level of practical experimentation is often referred and recommended as a key enabler for learning in Ubiquitous Computing because of its role in structuring the relationship between the conceptual aspects of the field and the reality of deploying information technology for the mundane realities of everyday life.

Lectures will be used to provide an initial background and quickly prepare everyone to the topic. The use of videos and the study of reference case studies will be used to complement the presentation of the topics and guide the study of the most commonly used approaches and issues. Student presentations and exercises will be used to promote engagement and exercise the analysis of existing work.

In the **System Report**, students will be asked to propose a particular system for Ambient Intelligence and a set of associated research questions. This will be an opportunity to build small but challenging systems that will help students in mastering

ambient intelligent technologies and best practices. While implementation is not required, practical evaluation of key technologies may be important in gaining some insight into some of the key issues involved, and will be strongly recommended. Simulation using virtual worlds may also be used not only to reduce hardware requirements for class but, most importantly, enable students to develop more interesting Ambient Intelligence systems and applications. The need to indicate research questions associated with the proposed system aims to stimulate students to go beyond the merely technical specification and exercise their analysis skills by identifying and describing the broad issues involved in creating ambient intelligence systems.
An intermediate version of this report will be delivered and presented half-way in the course. This intermediate version will focus on the State of the Art. Students have already chosen their topic and they should include a section in this intermediate report where they briefly describe and analyse previous research. This will be an opportunity for students to develop their research skills in searching and analysing previous work, while studying in more detail a particular topic that they find motivating. A presentation of the results to the class will also be part of the activity.

Assessment

Assessment will be based on the evaluation of the intermediate and the final system report. The intermediate report will be evaluated mainly based on its scope and on the ability to analyze, compare, relate and judge the relevance of previous research. The System Report will be evaluated on the innovation of the proposed system, on the coherence of the specification and on the broadness of the issues considered. Both reports include an oral presentation made to the class.

5. Main Bibliography

Within the topics of this course, and particularly at this level, there are no text books that can significantly cover the proposed program. Therefore, the key bibliography for the course will be mainly based on research papers. In this section, we indicate only the key bibliography that can be considered more generic and mandatory reading for all participants in the course.

Mark Weiser, "Some Computer Science Problems in Ubiquitous Computing," Communications of the ACM, July 1993. (reprinted as "Ubiquitous Computing". Nikkei Electronics; December 6, 1993; pp. 137-143.)

M. Satyanarayanan, "Pervasive Computing: Vision and Challenges," IEEE Personal Communications, vol. 8, pp. 10-17, 2001.

G. Banavar and A. Bernstein, "Software infrastructure and design challenges for ubiquitous computing applications,"Communications of the ACM, vol. 45, pp. 92 - 96, 2002.

Bell, G. and P. Dourish (2007). "Yesterday's tomorrows: notes on ubiquitous computing's dominant vision." Personal and Ubiquitous Computing 11(2): 133 - 143.

Rogers, Y. (2006). Moving on from Weiser's vision of of calm computing: engaging UbiComp experiences. Ubicomp 2006, Orange County, California, USA, Springer-Verlag.

Alex, S. T., H. Richard, et al. (2007). "Homes that make us smart." Personal Ubiquitous Comput. 11(5): 383-393.

Richard Harper, Tom Rodden, Yvonne Rogers, Abigail Sellen (Eds). HCI 2020. A report on the future of HCI. Microsoft Research. March 2008.

Kindberg, T.; Fox, A., "System software for ubiquitous computing", IEEE Pervasive Computing Magazine, vol.1, no.1, pp. 70- 81, Jan-Mar 2002

N. Davies and H.-W. Gellersen, “Beyond prototypes: challenges in deploying ubiquitous systems,” IEEE Pervasive Computing, vol. 1 No 1, pp. 26- 35, 2002.

R. Sharp and K. Rehman, “The 2005 UbiApp Workshop:What Makes Good Application-Led Research?,” IEEE Pervasive Computing, vol. 4 No 3, pp. 80-82, 2005.

B. Teaching Team

1. Coordinator

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2. Overview of the teaching team

The course will be conducted in collaboration between Rui José (University of Minho), Ricardo Morla (University of Porto), José Campos (University of Minho) and Paulo Novais (University of Minho). These researchers are all actively involved in ubiquitous computing and ambient intelligence research and together provide a valuable mix of complementary competences for the topics of this course.

Rui José is a member of the Ubicomp@UMinho team, a research group at Algoritmi, an ICT research centre of the Engineering School of University of Minho. This group has been actively engaged in ubiquitous computing research for some years, and has organised the first conference in this area in Portugal, CSMU'06, where Rui José was the Program Chair. In addition to the publication record, Rui José research experience in this area also includes the participation in several research projects and the regular contribution as a reviewer for the main conferences and journals in the field, including the Ubicomp and Pervasive conferences and the IEEE Pervasive Computing journal. Additionally, Rui José also has an extensive experience in teaching Ubiquitous and Pervasive Computing. He was the first Director of the MSc in Mobile Systems where he was responsible for the course on Ubiquitous Computing.

Ricardo Morla is actively conducting research in the field of Ubiquitous Computing and Ambient Intelligence. He is currently looking into immersive virtual worlds such as Second Life™ as a tool for simulation and prototyping of Ubiquitous Computing systems, as a middleware for Ubicomp applications, and as a tool particularly suited for teaching ubiquitous computing classes. Ricardo has a funded research project on this subject in collaboration with the University of California, Irvine, where he has lectured on distributed systems and mobility issues that are core to Ubiquitous Computing and Ambient Intelligence. Ricardo is also involved in other projects related to this field and is trying to create a research group on intelligent environments at his home institution; some of these projects he focus e.g. on the co-location of devices, on intermittent interaction, and on overlays for intelligent transportation systems, in addition to other projects that leverage on virtual worlds.

José Creissac Campos is a member of the Foundations and Applications of Software Technology research group at CCTC (Sciences and Computing Technologies Centre), a research centre from the Engineering School of the University of Minho. His research interests lie in the intersection of Software Engineering and Human-Computer Interaction (HCI). In recent years he has developed a strong interest in mobile and ubiquitous computing. He is particularly interested in the problems faced when trying to design, analyse and develop the human interaction for such heterogeneous contexts as those present in mobile and ubiquitous computing settings. He serves as Programme

Committee member in a number of conferences, including IFIP TC13 INTERACT, DSV-IS, and ACM EICS. He was programme co-chair of Interacção 2008, the third Portuguese HCI conference. He has led and participated in a number of funded research projects. For the last 7 years he has tough and been responsible for a number of HCI courses at the postgraduate level.

Paulo Novais is a lecturer of Computer Sciences at the Department of Informatics, in the University of Minho and he is a member of the Artificial Intelligence research group at CCTC (Sciences and Computing Technologies Centre), a research centre from the same university In the last years he has tough and been responsible for a number of courses on Intelligent Agent and on Intelligent Systems at the graduate and postgraduate level. His current research directions span the fields of Knowledge Representation and Reasoning Systems, Agent and Multiagent Systems and Learning applied to Ambient Intelligence and AI and Law. He is supervising Ph.D. (3) and M.Sc. (15) projects and he has led and participated in a number of funded research projects. He is Vice-president of APPIA, the Portuguese Association for Artificial Intelligence.